EFFECTS OF LONG DURATION SPACEFLIGHT ON VENOUS AND ARTERIAL COMPLIANCE: BED REST

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BACKGROUND

The visual impairment and intracranial pressure (VIIP) syndrome is a spaceflight-associated medical condition consisting of a constellation of symptoms affecting ~35-50% of astronauts who have flown long-duration missions to the International Space Station (ISS). VIIP is defined primarily by the development of optic disc edema and other ocular structural changes that may contribute to visual acuity changes. The leading hypothesis suggests an elevated intracranial pressure secondary to spaceflight-induced cephalad fluid shifts is a contributing factor. Loss of visual acuity could be a significant threat to crew health and performance and have significant consequences during and post spaceflight.

PURPOSE

The primary objective was to determine whether a high sodium diet during bed rest induced alterations in vascular compliance and was related to the incidence of VIIP. Ocular structural and functional measures and vascular ultrasound of the head and neck were acquired in bed rest subjects completing 10-14 days in 6° head-down tilt.

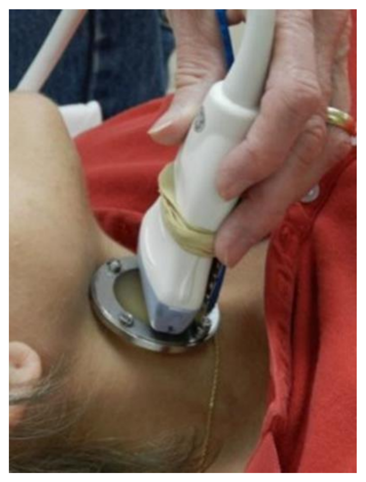
SPECIFIC AIMS

To evaluate the effect of a headward fluid shift with sodium ingestion similar to ISS astronauts on vascular compliance and on the development of VIIP in young and old subjects.

METHODS

- We studied 11 healthy men ($VO_2max \geq 30$ ml/kg/min) in two age groups (25-35 and 45-55 yrs old) during a 10-14 day 6° head-down bed rest, a well-accepted analog of spaceflight.
- Standard NASA bed rest conditions were maintained except that sodium intake was 40% greater than previous studies to mimic the consumption of ISS astronauts. Dietary sodium was 64.4 mg/kg/d or 2.8 mmol Na^+/kg/d.
- Testing occurred prior to bed rest (BR-1), at the end of bed rest (BR+0), and after 3 days of reambulation (BR+3).
- Vascular measures, ocular ultrasound and intraocular pressure (IOP) via rebound tonometry were acquired at 5 tilt angles (+20°, +10°, 0°, -10°, and -20°).
- Internal jugular venous area (n=11) was imaged at end expiration.
- Internal jugular venous pressure was measured non-invasively (n=6) using a novel device – VeinPress. This device estimates venous pressure by measuring the amount of pressure necessary to compress the vein as visualized by ultrasound.
- Optical coherence tomography (OCT) images were acquired while seated upright before and after bed rest.
- Plasma volume was measured using the carbon monoxide re-breathing method on BR-1, BR7, BR+0, and BR+3.

Subject in 6 degree head-down bed rest



VeinPress used to measure venous pressure non-invasively

RESULTS

All data are presented as mean ± SD.

Subject demographics

	Young (n=7)	Older (n=4)
Age, yr	28.6 ± 3.7 (25-35)	49.3 ± 3.3 (45-53)
Weight, kg	77.3 ± 10.7 (64-86.5)	90.2 ± 3.2 (87.3-93.6)
Height, cm	179 ± 3.9 (174-183)	179 ± 2.2 (177-182)
BMI, kg/m^2	24.2 ± 3.5 (19.1-28)	28.1 ± 1.2 (27.2-29.9)

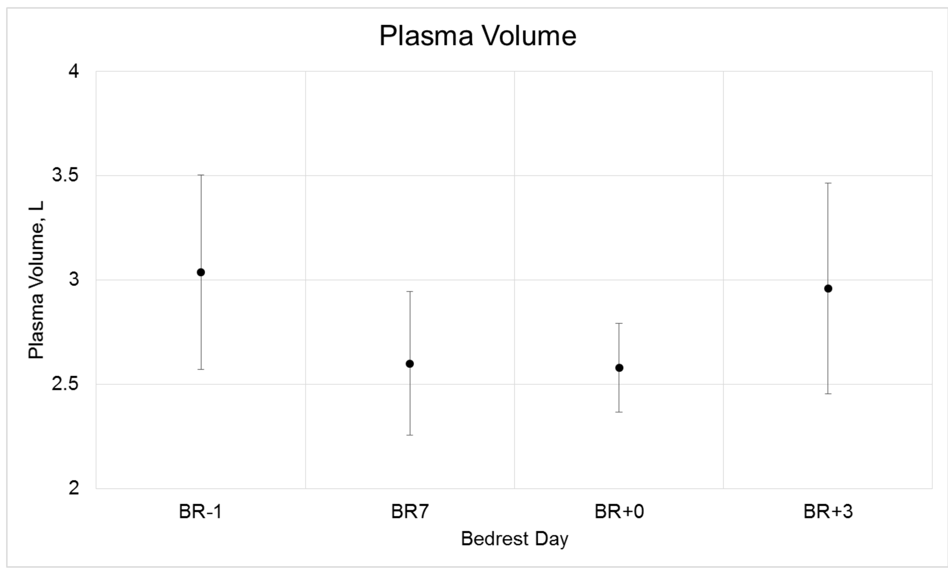
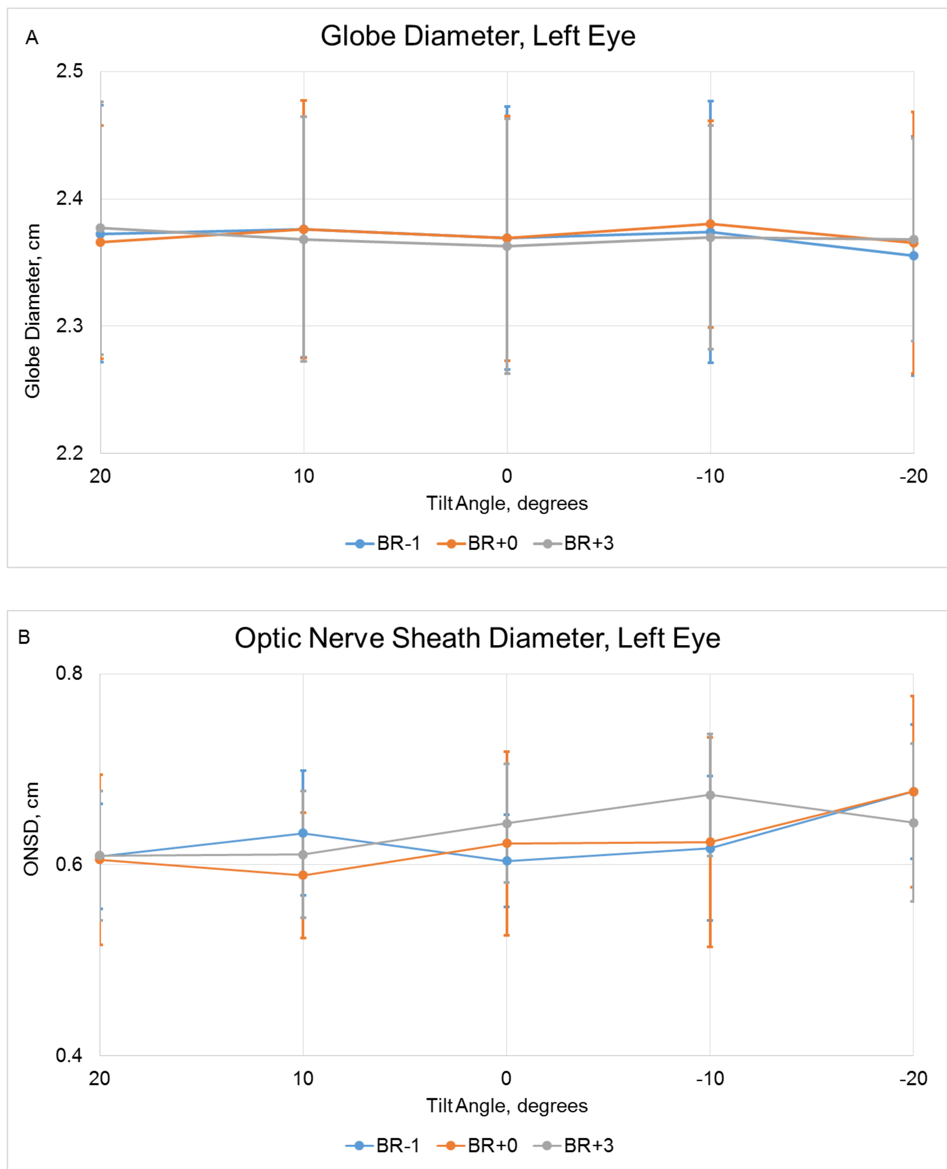


Figure 1. Plasma volume before, during, and after an up to 14 day bed rest with 40% higher dietary sodium intake than the NASA standard bed rest diet.



Figures 2.: Ocular Structures measures via ultrasound. The globe diameter (A) and (B) optic nerve sheath diameter (ONSD) did not change with position or bed rest day.

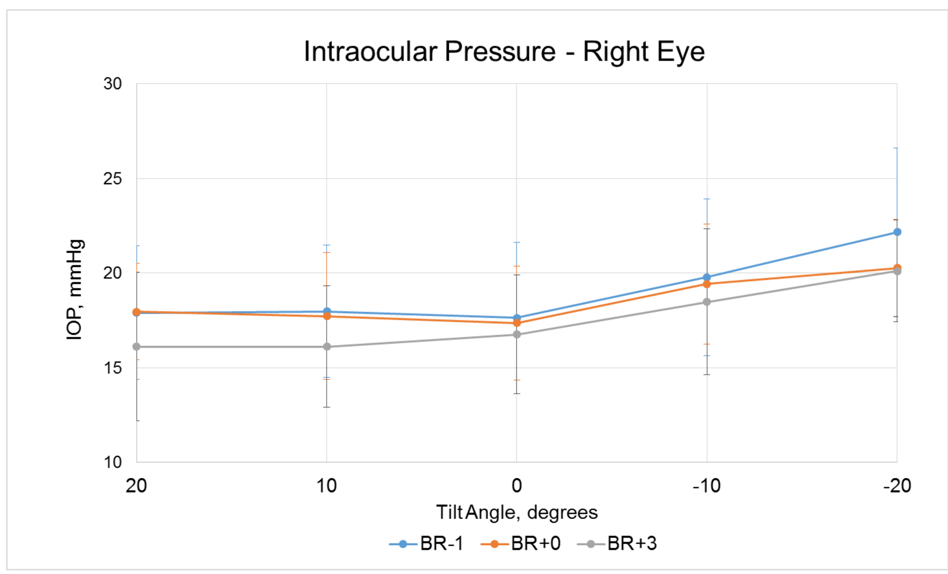


Figure 3.: Intraocular Pressure measured by rebound tonometry.

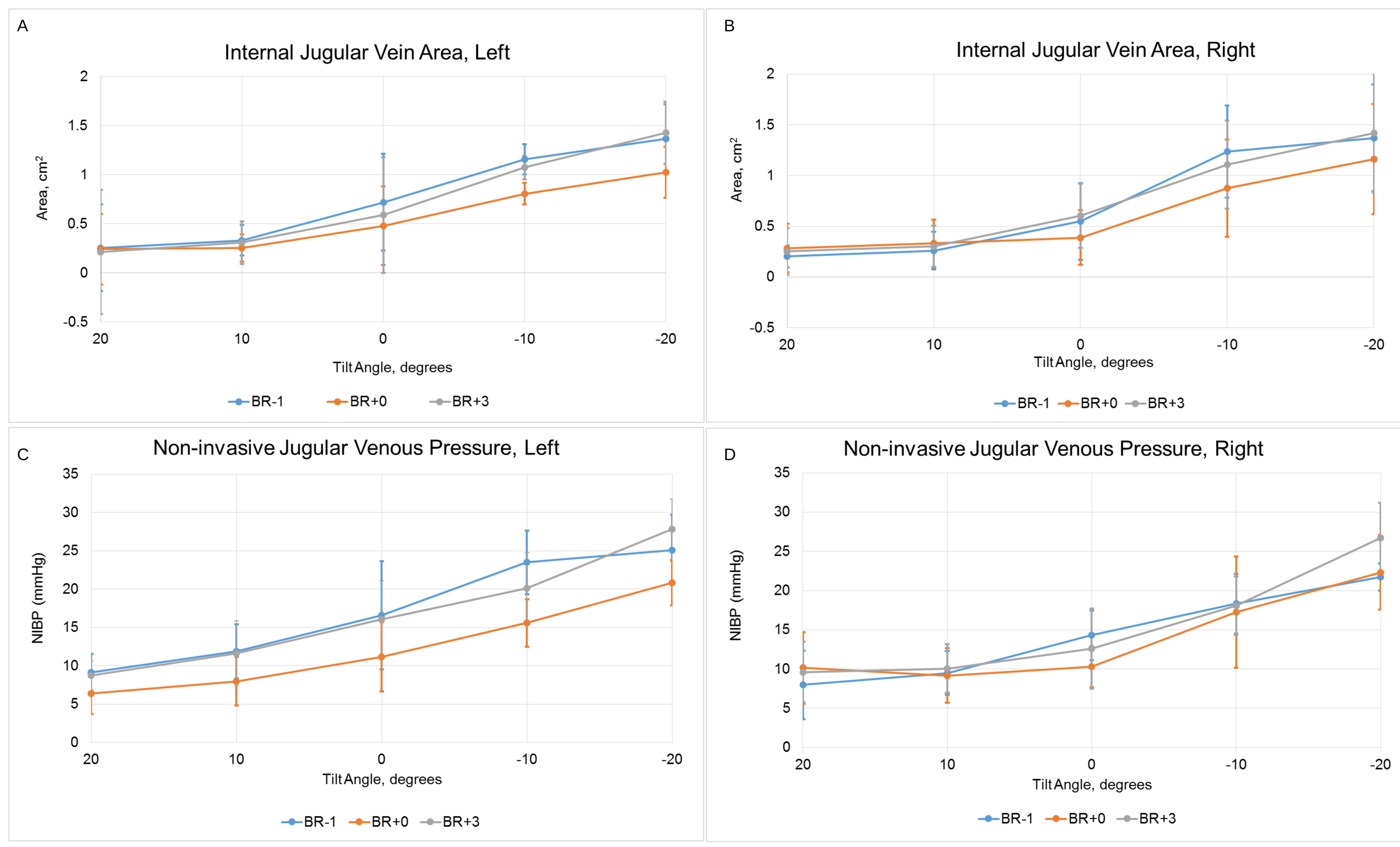


Figure 4 (A) Left and (B) right internal jugular venous area and (C) left and (D) right non-invasive venous pressure (VeinPress) as a function of Tilt Angle

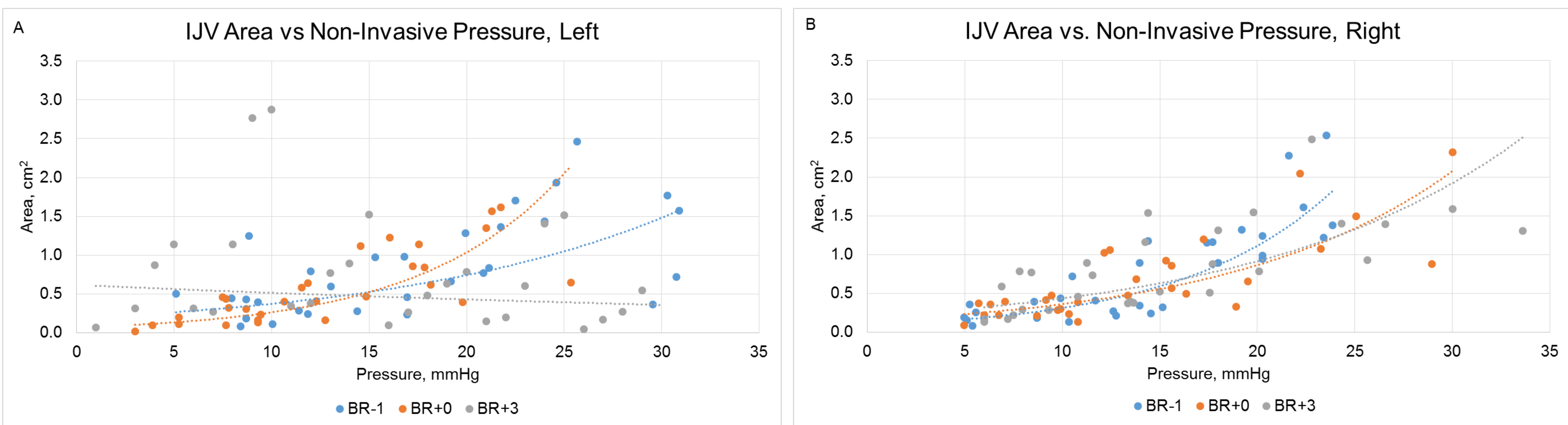


Figure 5 (A) Left and (B) right internal jugular venous area vs. non-invasive venous pressure (VeinPress) (n=6).

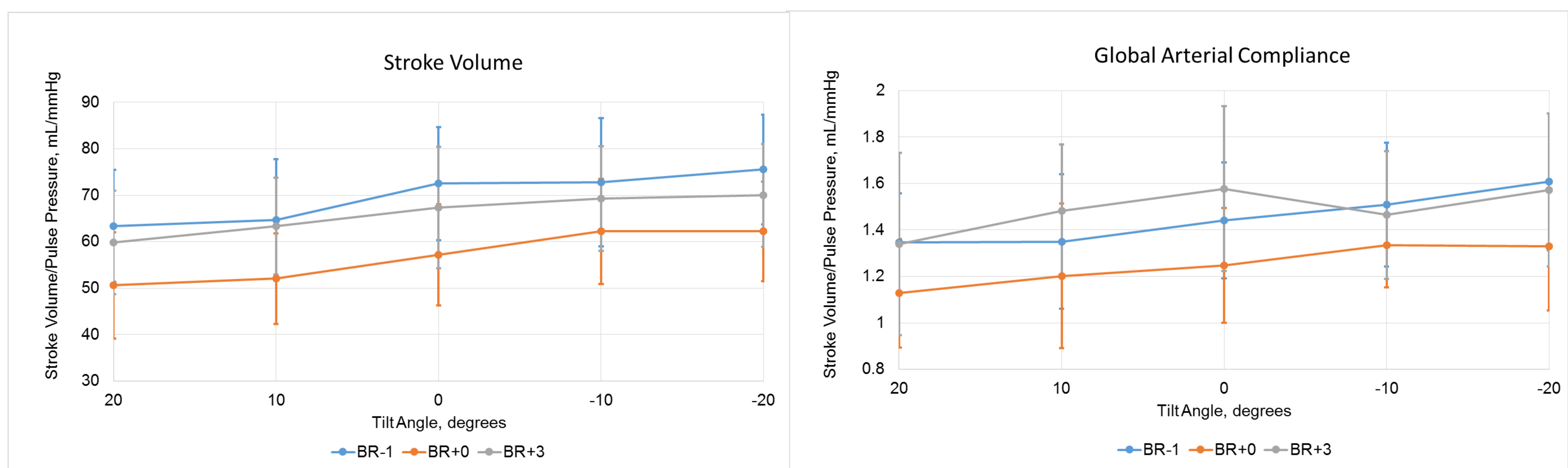


Figure 6. Stroke Volume (A) and Global arterial compliance (B) calculated as stroke volume divided by pulse pressure (systolic – diastolic pressure).

SUMMARY

PLASMA VOLUME: Similar to previous bed rest studies, plasma volume decreased during bed rest and recovered by R+3. The higher sodium diet did not protect subjects from plasma volume loss.
OCULAR ULTRASOUND: Axial length did not change after an up to 14-day 6° head down bed rest. In addition, axial length did not change with acute positional changes.
INTRAOCULAR PRESSURE: IOP increased with head-down tilt, but was not different following bed rest.
INTERNAL JUGULAR VEIN (IJV): As expected, the IJV was almost collapsed during positive tilt angles and the area increased with head down tilt. Relative to tilt angle, IJV area appeared lower at the end of bed rest, but recovered to pre-bed rest levels by R+3.
GLOBAL VASCULAR COMPLIANCE: Vascular compliance at all angles appears to be lower post bed rest than before bed rest and returned to pre-bed rest values by R+3. This reflects a similar pattern as the stroke volume response, which is influenced by the change in plasma volume.
OPTICAL COHERENCE TOMOGRAPHY (not pictured): Optical coherence tomography measures, including disc area and retinal nerve fiber layer thickness, remained unchanged after bed rest.

Vascular changes observed after 14 days of bed rest in young and older subjects follow, and may be related to, the loss and subsequent recovery of plasma volume. However, ocular structural changes associated with VIIP did not develop during this study. Whether vascular remodeling or VIIP symptoms would develop with a high salt diet during longer bed rest remains unknown.

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